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ABSTRACT

In this paper two models of memory are described and implications for hearing impaired students noted. Research on linguistic encoding in short-term memory is also reviewed. The majority of studies suggest that for hearing/speaking Ss, encoding bases are primarily phonological or sound-based, regardless of presentation mode. For deaf/signing Ss, encoding bases appear to be primarily cherological or sign-based, apparently regardless of presentation mode. However, evidence that hearing signers code signs cherologicaly brings into question the earlier generalizations regarding encoding bases in short-term memory. The need for research on linguistic encoding bases particularly as a function of signed or spoken input to deaf and hearing Ss is noted. (Author/CL)

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Linguistic Encoding in Short-term Memory: An Overview

by

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In this paper two models of memory are described. Research on linguistic encoding in short-term memory is also reviewed. The majority of studies suggest that for hearing speaking subjects, encoding bases are primarily phonological or sound-based, regardless of presentation mode. For deaf signing subjects, encoding bases appear to be primarily cherological or sign-based. Again, this appears to be regardless of presentation mode. There is, however, some evidence that hearing signers code signs cherologically (Crittendon, 1974). This brings into question the earlier generalizations regarding encoding bases in short-term memory. Future research may need to reinvestigate linguistic encoding bases particularly as a function of signed or spoken input to deaf and hearing subjects.

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Introduction

The structure, content, and processes of memory have been of interest to Man since the time of Aristotle. Over the years researchers have attempted to develop models which accurately describe and explain memory. The research to be reviewed here will examine the bases for encoding linguistic material into memory, specifically into short-term memory. In the next section, two proposed models of memory will be presented. The phenomenon referred to as short-term memory will be discussed and past research on encoding bases for linguistic material will be summarized in relation to the hearing-impaired learner.

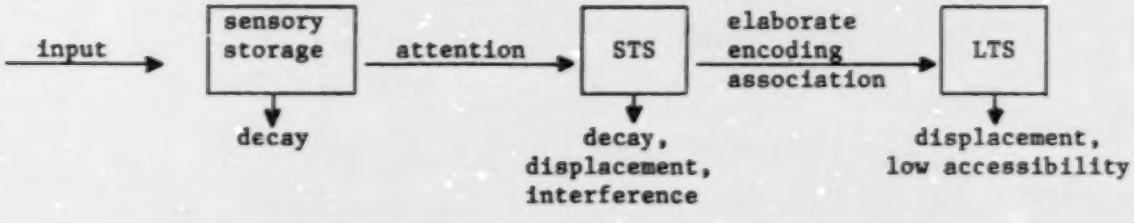
Memory Structures and Processes

Multi-Store Model

Broadbent (1958) initially characterized memory as consisting of different holding "stores." This characterization was further developed by several psychologists, most notably Atkinson and Shiffrin (1968, 1971), whose model includes a sensory register, a short-term store (STS) and a long-term store (LTS). Each is considered as a storage place for information (Figure 1).

Figure 1

Atkinson and Shiffrin's Model of Memory



Sensory register. As shown in Figure 1, information from the external environment enters the information-processing system through the sensory register. The sensory register holds unanalyzed information from the sensory receptors for

very brief periods of time (typically for .25 to 2 seconds, according to Waugh & Norman, 1965). The sensory register maintains its contents in iconic form (Crowder & Morton, 1969; Neisser, 1967).

Short-term store. When attention is focused on items in the sensory register they are transferred to STS. These items must be rehearsed or continually attended to in order to be maintained. Coding bases appear to be primarily sound-based (Sperling & Speelman, 1970). Shulman (1972) has shown that semantic encoding may be employed, and Kosslyn and Joliceur (1980) have also shown that visual coding may be employed, depending on the task. The capacity of STS is generally considered to be 7 ± 2 elements (Miller, 1956). Others, such as Simon (1972), have suggested this capacity to be less than 7 items, and Case (1972) has suggested that the capacity may change developmentally. Waugh and Norman (1965) and Perfetti and Lesgold (1977) suggested that information is lost by being displaced or "bumped-out" by new information entering STS. Decay may also be a cause of information loss (Atkinson & Shiffrin, 1968). The memory trace has been found to last 5 to 20 seconds (Kintsch, 1974; Waugh & Norman, 1965). Retrieval is automatic and may be facilitated by temporal or phonemic cues (Craik & Lockhart, 1972).

Long-term store. Information enters this store through elaborative rehearsal and organization of the material (Craik & Lockhart, 1972; Kintsch, 1974). It appears that either the syntactic or semantic structure may be stored, depending on task demands (Anderson & Bower, 1973; Kintsch, 1974). LTS appears to have no known limit (Craik & Lockhart, 1972). Information may be totally displaced (Loftus & Loftus, 1980), or accessibility to it may be low (Anderson & Bower, 1973). Trace duration is from minutes to years, and retrieval is either via search (serial or parallel) or direct access (Anderson & Bower, 1973; Kosslyn &

Joliceur, 1980; Norman & Rumelhart, 1975; Wickelgren, 1977). Search can be initiated by either internal or external contextual cues (Anderson & Bower, 1973).

Levels of Processing Model

In response to the multistore model of Atkinson and Shiffrin, Craik and Lockhart (1972) have proposed a "levels of processing" model. Information is processed to one or more of several levels. The "deepest" processing allows the information to be encoded at a semantic level. Processing has proceeded from a surface parsing of the information (verbal or non-verbal) to, in some cases, this deepest semantic level. At this deepest level the information is more elaborately processed than at other levels. It is matched and associated with other information which is also at this level. There is not simply a passing of information from one box to the next as in the multi-store model; there is a more elaborative, associative, analytical process which brings the new information in contact with older cognitive structures of information. A continuum of analysis from surface to semantic level is posited. Long-term retention is a positive function of the depth of processing. Short-term retention is due to the information being "recirculated" via maintenance rehearsal at a level of processing where it can be quickly retrieved. Such recirculation is limited in its capacity and is referred to as Type I processing. The deeper analysis and processing is termed Type II processing, or sometimes "elaborative rehearsal" (Craik & Lockhart, 1972; Craik & Watkins, 1973).

The Phenomenon of Short-term Memory

It is beyond the scope of this paper to investigate the theoretical credibility of either the mutli-store or levels-of-processing models. The focus of the review will be on a point held in agreement by both groups of theorists. Atkinson

and Shiffrin (1968, 1971) and Craik and Lockhart (1972) suggest that there are similar kinds of memory. These types are sensory memory, short-term memory (STM), and long-term memory (LTM). These types are not the same as the stores in the stage model nor as the levels in the levels-of-processing model. Rather, they refer to the characteristics of the information which may be held/processed at a particular store/level.

STM is of particular interest because it entails active attention to information, including the manipulation of information through synthesis and rehearsal. STM appears to function as a central processor for linguistic and non-linguistic information. According to Atkinson and Shiffrin (1971), the analysis of incoming information is accomplished by the matching of information in STM with previously stored information in LTM. This matching process enables an individual to interpret new inputs and to associatively organize new inputs with each other and with previously learned information in LTM. Through investigation of the coding bases for linguistic material in this central processor, the organization and representation of language in memory may be more clearly described and defined.

STM: Types of Encoding

This section will review the past research on encoding of linguistic material in STM. It will describe and discuss the design and results of studies which have found evidence for phonological, semantic, and cherological encoding. A tentative conclusion about encoding of linguistic material in STM is made.

Phonological Encoding

In STM experiments, hearing subjects have shown a strong tendency to encode linguistic material phonologically (Baddeley, 1966, 1968; Conrad, 1962, 1963, 1964, 1971). This encoding has occurred even when the stimuli were printed words or letters (Baddeley, 1966; Conrad, 1964, 1972; Conrad & Hull, 1964; Murray, 1967;

Sperling, 1960, 1963). The claim that phonological encoding is preferred in STM has been based on the analysis of intrusion errors, on subjects' recall performance on lists of phonological related words compared to other list types, and on the results of experiments that study interference with target items by items that may or may not sound like the target (Sperling & Speelman, 1970).

Intrusion error studies. The intrusion errors which occurred in prior experiments were generally phonologically based. These errors consisted of words or letters which sound like the target item. For example, the target letter C is sometimes replaced by the phonologically related Z rather than the graphemically related O during recall (Bellugi, Klima, & Siple, 1975). Similarly, the word cat will often be recalled as the phonologically related hat rather than as the semantically related lion. Murray (1968) and Wickelgren (1965a, 1965b) found that phonologically based intrusions dominated the short-term recall errors of their subjects when the stimuli were presented auditorially. Phonological intrusions have also been found in the recall performance of subjects when the stimuli are presented visually (Baddeley, 1966; Conrad, 1962; Hintzman, 1967; Murray, 1968; Sperling, 1960, 1963).

Phonological intrusions also appear in spontaneous speech. For example, a person sometimes substitutes easy for eager as in "John is easy to solve this problem" (Fromkin, 1980). Similar intrusions have been found by Shattuck-Huffnagel and Klatt (1980), Cohen (1966), Nooteboom (1969), Van den Broecke and Goldstein (1980) and Fromkin (1971).

Browman (1980) and Garnes and Bond (1980) have shown that errors in auditory perception of linguistic material are also often phonologically based. Mishearings such as a snip of the ear for a slip of the ear sometimes occur (Garnes & Bond, 1980). Conrad (1962, 1964) also found phonologically based slips of the ear

when masking speech with white noise. When intrusions occurred under this condition, listeners generally reported that they heard a letter which was phonologically similar to the spoken letter that was masked.

Recall performance studies. Subjects generally recall phonologically related lists less well than other types of lists. This result was found by Conrad, Baddeley, and Hull (1966), Conrad and Hull (1964), Murray (1968), Laughery and Pinkus (1966) and Sperling (1963), who compared the recall of phonologically similar and unrelated letters presented visually. The same results occurred in the studies by Wickelgren (1965b), Murray (1968), Laughery and Pinkus (1966), and Laughery (1963) when comparing recall of lists of phonologically similar and unrelated words. Baddeley also included lists of semantically and graphemically similar words in his study. Both Conrad and Baddeley presented stimuli visually, and Baddeley also included an aural presentation condition in his study. In both studies phonologically related lists were recalled significantly less well than any other list type utilized in the experiments. This type of result is taken to suggest that phonologically related items are encoded in a similar fashion to STM, thus causing confusion during recall and the lower recall performance.

Distractor items studies. Some researchers have investigated how different types of items may distract the person from the to-be-remembered items in short-term recall. In the typical paradigm for this type of study, subjects were first presented words (Dale & Gregory, 1966) or letters to be remembered (targets) (Conrad, 1967; Dale, 1964; Wickelgren, 1965c), followed by words or letters, respectively, which were phonologically similar or dissimilar to the first stimuli (distractors). The subject read aloud or copied the distractors after which they immediately attempted recall of the target items. In each study the recall performance of the subjects was significantly poorer when the distractors were

phonologically similar to the targets than when they were not. Dale and Gregory also found that semantically related distractors had an adverse effect on recall performance.

Wickelgren (1966) used a technique similar to that described above to investigate short-term recognition. Subjects heard one letter (the target) which was followed by a 12-letter auditory distractor. Following the distractor, subjects heard one more letter, the test letter. They were to decide if this test letter was identical to the target letter they heard first. False recognition rates were significantly higher when the test letter was phonologically similar to the target letter than when it was not. Also, when the distractor list included letters that were phonologically similar to the target letter, the accuracy of comparison between the target and test items was significantly poorer than when target and distractor list were phonologically unrelated.

Murray (1967) asked hearing subjects to articulate items that were phonologically similar or dissimilar to the targets while the targets (letters) were being presented. Subjects' recall of target letters was significantly poorer when phonologically similar distractors were articulated. These results have been taken to suggest that distractors which are phonologically similar to the targets are coded in a similar fashion to the targets in STM. These similar encodings then cause confusion during recall and the lower recall performance. Some researchers have interpreted the results of the studies reviewed thus far to mean that phonological encoding is the preferred or natural encoding style for linguistic material (Sperling & Speelman, 1970). Some studies reviewed below suggest that this interpretation may need to be reconsidered.

Semantic Encoding

Research with hearing subjects has indicated that linguistic material may be coded semantically in STM (Shulman, 1970, 1971, 1972; Wetherick, 1975; Wickens,

1972). In one study, Shulman (1972) sequentially presented lists of 10 printed words followed immediately by a letter to indicate if the subject was to judge a probe word as being identical, phonologically related, or semantically related to a word in the initial list. The probe word followed the letter immediately. The results showed that subjects could make correct judgements of semantic similarity quite accurately (72%). In a review of literature on STM encoding, Shulman (1971) has suggested that both semantic and phonological encoding can occur. However, he concludes that phonological encoding dominates STM unless the task specifically demands semantic encoding.

Baddeley (1972) argues that the semantic encoding found in STM is due to semantically coded retrieval rules which are stored in long-term memory. These rules may be used to interpret the phonologically coded contents of STM. Thus, he attributes the semantic encoding that appears in STM to long-term memory processes and finds no reason to abandon the simpler generalization that phonological encoding dominates STM.

Cherological Encoding

Research with deaf subjects, on the other hand, has suggested that some individuals may prefer nonphonological encoding. Wallace and Corballis (1973), Lock and Locke (1971), and Conrad (1971) found that deaf subjects may encode verbal items based on the shape of the stimuli or based on a fingerspelling code. Wilbur (1974) has suggested that deaf people who know American Sign Language (ASL) may code cherologically in STM (i.e., based on the formational parameters of sign) even when printed words are the stimuli. The major cherological parameters of a sign are: handshape, place of articulation, and movement (Stokoe, Casterline, & Croneberg, 1965). Newkirk, Klima, Pederson, and Bellugi (1980) have added the minor parameters of: contacting region of the hand, orientation of the hand, and

hand arrangement (i.e., number of hands involved in a sign and the activity of the hand[s]).

Using deaf native signers of ASL, Bellugi and Siple (1974), Klima and Bellugi (1979), Bellugi, et al., (1975), Poizner, Bellugi, and Tweney (1979), Grosjean, Teuber, and Lane (1979), and Shand (1980, 1982) have all found evidence that deaf signers tend to encode linguistic material cherologically in STM. This claim is based on intrusion errors, subjects' recall of performance on lists of items that are signed similarly, compared to lists of cherologically dissimilar items, and research on the perception of signs.

Intrusion error studies. Bellugi and Siple (1974) and Bellugi, et al., (1975) reported that cherologically based intrusion errors dominated the recall errors of their deaf subjects. This result occurred when signs were presented as the stimuli to be recalled. For example, the sign UNCLE was intruded for the sign HORSE. These two signs are cherologically similar. The only cherological difference is in the movement parameter (Bellugi, et al., 1975). Such intrusions occurred whether the subjects' recall response was written or signed (Bellugi & Siple, 1974).

"Slips of the hand" in signers (comparable to slips of the tongue in speakers) have been collected by Newkirk, et al. (1980). They found that many intrusions that occurred in the spontaneous conversations of deaf native ASL users were cherologically similar to the target signs. For example, PARENTS was articulated when DEAF was intended. Only handshape differs significantly between these two signs.

The author has also observed cherologically-based "slips of the eye" by young deaf signers. For example, during a spelling test, two deaf 6-year-olds wrote the word bed when shown the sign SAD. These two signs differ only in movement. They have the same handshape and place of articulation. The second instance also

occurred with 6-year-olds; the sign SEVERAL was misread as FRISBEE, which prompted the children to become excited over the prospect of playing frisbee as it was nearly recess time. The two signs differ only in movement. A third example was provided by a 9-year-old; twice in succession he tried to recall the spelling of the word before after it had just been erased from the board. Both attempts produced B-E-F-O-U-E. The letters U and R are similar manually. They use the same two fingers in the same orientation and location. In R the fingers are crossed, while in U they are straight.

Recall performance studies. Shand (1982) presented deaf subjects cherologically-related, phonologically-related, and unrelated lists of items for immediate recall using both sign and print presentation conditions. Subjects' recall in both presentation conditions was significantly poorer for cherologically-related lists as compared to recall of other list types. Klima and Bellugi (1979) obtained the same results when presenting cherologically-related signs and totally unrelated signs for immediate recall. Poizner, et al. (1979) also found a significant decrement in recall of cherologically-related signs as compared to recall of unrelated signs. In a second study these authors found a weak adverse affect on recall for semantically related signs as compared to recall of unrelated signs. This finding led them to conclude that short-term encoding for deaf signers is not semantically-based but rather cherologically-based. Bellugi and Siple (1974), Bellugi, et al. (1975), Klima and Bellugi (1979), and Shand (1982) have also suggested that cherological encoding is preferred by deaf signers.

Perception studies. A study of the perception of sign language also suggests that signs are processed cherologically in STM by deaf subjects. Grosjean, Teuber, and Lane (1979) asked subjects to reproduce a sign that had just been flashed on a television screen. Subjects were also asked to guess what that sign was and to estimate their confidence in their guesses. The results showed that

subjects' reproductions and guesses were based on the cherological components of the signs, and not on any phonological components of the English translation, semantic similarity, or English graphemes.

The studies discussed above have addressed short-term recall and recognition performance for linguistic material and the intrusion errors that occur in these STM experimental settings. Also, intrusions that occur in spontaneous communication and studies of perception have been described. It appears that hearing-speaking subjects show a tendency for phonological encoding, and deaf-signing subjects show a tendency for cherological encoding of linguistic material in these situations. However, the encoding bases used by hearing speakers who are fluent signers and deaf signers who have intelligible speech have not been addressed. Presentation of stimuli orally and manually to these subjects may help to determine if encoding bases are as "fixed" as past research would indicate. Another unresolved issue is whether the type of encoding which a person uses for linguistic material is a function of hearing ability, early linguistic experience (i.e., first language learning), or later linguistic experience (learning to read, second language learning, etc...). Research addressing each of these variables will be discussed below.

Role of Early Linguistic Experience and Hearing Ability

Shand (1982) suggested that early linguistic experience may establish a person's preferred coding style for STM. However, the data he presented only suggest that coding style is a function of hearing ability (i.e., deaf people who know signs prefer a cherological code, and hearing people who know speech a phonological code). Studies by Conrad (1973, 1979) provide further support for the notion that linguistic coding style may be a function of hearing ability. Conrad found that hearing subjects made significantly more phonologically-related intrusions than phonologically-dissimilar intrusions during recall. Deaf subjects

did not show this same tendency and made significantly fewer phonologically-related intrusions than hearing subjects did.

Role of Later Linguistic Experience.

Donahoe and Wessells (1980) suggest that later experience (in this case, reading experience) may be the key to the utilization of a phonological code. They cite Hagen and Stanovich (1977) and Conrad (1971) as evidence. Hagen and Stanovich found that the tendency to label visual stimuli verbally (i.e., phonologically encode) increased continually after age 5. Conrad found that the normally poorer performance on recall of phonologically-related word lists did not occur with 3-5 year olds. However, at age 6, children recalled phonologically-different words significantly better than phonologically-related words. This difference increased with age. Donahoe and Wessells (1980) noted that the initiation of reading instruction around age 6 may underlie this interaction between the age of the subject and the phonological characteristics of the stimuli.

Although the research of Hagen and Stanovich (1977) and Conrad (1971) is consistent with a view that coding performance results from later linguistic experience, it does not totally rule out the early experience hypothesis. For hearing people the tendency to encode phonologically may develop gradually and coincidentally become prominent at the time reading instruction begins. The preceding studies did not manipulate reading instruction as an independent variable, and thus a causal relation cannot be determined by these studies. In fact, it is possible that the tendency to encode stimuli phonologically underlies one's readiness for reading instruction.

Crittendon (1974) has more directly addressed the question of what determines coding style. Hearing subjects who had completed a beginning college sign language course were presented a videotape of individual signs produced at normal

signing rate without voicing or speech lip movement of the English translation. The subjects were asked to write an English word for each sign they saw. In Experiment 1, 77 signs were presented to 30 subjects and in Experiment 2, 25 signs were presented to 29 subjects. There were 412 cherologically-based errors in the first experiment and 75 cherologically-based errors in the second experiment. These data suggest that hearing subjects who know some sign language may misinterpret a sign along cherological parameters. Crittendon stated that only cherologically-related data were analyzed and presented in the published report. It cannot therefore be said that phonological encoding was not also occurring or would not also have occurred if task demands had been similar to those in the recall experiments reviewed earlier. In a more demanding task the subjects might have recoded the signs based on the phonological components of their English translations. Crittendon's data, however, lend some support to the hypothesis that coding style can be a function of later linguistic experience (in this case second-language learning), rather than a function strictly of hearing ability or of early linguistic experience (first-language learning). However, more research is needed to strengthen this hypothesis.

Conclusion

Two models of memory and research on linguistic encoding in short-term memory have been reviewed. The prior conclusions that short-term linguistic encoding for hearing subjects is primarily phonologically-based, and that for deaf signers it is primarily cherologically-based, must now be re-examined. Hearing persons who are fluent signers and deaf signers with intelligible speech may provide a different view of primary coding bases. Stimuli should be presented in several different modalities, particularly in the oral and manual modalities for each of these subject groups.

The issue of what determines preferred coding style must also be addressed. Variables such as level of hearing, early linguistic experience, and total linguistic experience must be manipulated to help answer this question. Research to date has not provided a conclusive answer. The question for future research may not be, "How do all people encode linguistic information in STM?" but rather, "Who codes how, under what conditions?"

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